(12) UK Patent Application (19) GB (11) 2 053 876 A

(21) Application No 8020086
(22) Date of filing 19 Jun 1980
(30) Priority data
(31) 792077
(32) 2 Jul 1979
(33) Finland (FI)
(43) Application published
11 Feb 1981
(51) INT CL³
C04B 31/00
(52) Domestic classification
C1A 424 510 M12 M13
PF5
(56) Documents cited
GB 1520335
GB 1417685
GB 1400854
GB 1165897
GB 1153388
GB 660149
(58) Field of search
C1A
C1J
C1K
(71) Applicants
Flowcon Oy, Roineenkatu
18, 37600 Valkeakoski,
Finland
(72) Inventor
Bengt Forss
(74) Agents
Withers & Rogers

# (54) Process for manufacturing lightweight aggregate

(57) A process for manufacturing lightweight aggregate pellets comprises sintering finely divided industrial waste, such as fly ash or enrichment and flotation waste, as basic material in a rotary kiln together with water-saturated binders in the form of sludge or liquid, sprayed onto the basic material before the formation of the green pellets prior to sintering. The spraying is carried out intermittently or continuously by means of, e.g., nozzles.

GB 2 053 876 A

SPECIFICATION

**Process for manufacturing lightweight aggregate out of industrial waste**

The present invention concerns a process for manufacturing lightweight aggregate pellets out of finely divided industrial waste, such as fly ash, enrichment and flotation waste, and dust; as basic material according to which process

— at least one binder is brought into contact with the basic material to form green pellets, and

— the green pellets are sintered in a rotary kiln to form the final pellets.

In the field of concrete construction work, in certain cases, a material is required that has properties that cannot be obtained by using concrete types based on conventional aggregate. Such special cases may be, e.g., poor ground conditions, the desire to achieve high carrying capacities as compared with the own weight of the construction, or the requirement of better heat-insulating capacity as compared with the conventional concrete materials. Occasionally these requirements can be met technically by means of concrete of normal composition, but the solutions then become correspondingly heavier economically. Thus, within the construction industry, there is a general tendency towards constructions of concrete of lower weight and higher porosity, without loss of the favourable properties that have been achieved earlier. One method is to replace the aggregate made of natural stone by an aggregate material that has been produced artificially and has lower weight and higher porosity, a so-called lightweight aggregate. Concrete made of such an aggregate is analogically called lightweight concrete.

The preparation of lightweight aggregate with clay, shale, perlite, and other natural raw-materials as starting material is generally known. Likewise, it is known to use as starting material industrial waste, such as fly ash from coal-burning power plants, enrichment and flotation waste, waste from coal mines, slag, etc.

The known processes briefly involve that the starting material together with additives is, with the aid of water, worked into a soft mix. This mix is, in machines designed for the purpose, formed into granules, so-called green pellets, which are thereupon sintered. In the sintering process, the organic components are burnt away, whereby pores remain in the pellets. At the same time, water and other volatile substances escape in gaseous form, which results in expansion and increased volume in certain materials. The final result is solid porous pellets with considerably lower density than the density of natural rock.

According to a known process for the manufacture of lightweight aggregate out of industrial waste, an appropriately moist mix is prepared out of the waste, e.g., fly ash, and water, possibly together with other additives. After pre-mixing and homogenization in an activator, the mix is fed onto an inclined rotary granulating plate. During spraying of water at appropriate quantities, green pellets of spherical form are hereby formed on the plate. After the green pellets have received a desired size, they are passed from the plate and carried forward to a sintering process.

The difficulties in the manufacture of an acceptable lightweight aggregate on the basis of finely divided waste are, however, still great. Below, the greatest difficulties in the implementation of the processes known to-day will be given:

1. The green pellets cannot be given the mechanical strength that is required for the further transporation and heat treatment.
2. Owing to the poor strength of the green pellets, such sintering methods must be selected in which the green pellets are at rest during the sintering process. Generally known and most commonly used are the so-called sinter-belt plants. Here the green pellets rest in the form of a bed of a thickness of about 20 to 30 cm on an endless belt running slowly through the sintering furnace.
   In the thick immobile bed any expansion of the green pellets becomes impossible, at the same time as the pellets are sintered to each other. The result is a more or less firmly sintered-together mix which must be crushed and results in sharp-cornered aggregate pellets. The methods differ from each other only in respect of operations intended to reduce this sintering-together. At the same time, sinter-belt processes, however, require that the sintered mix is crushed after the sintering.
   The pellets obtained in this way yield an aggregate of heavy type. The pellets have sharp edges and open pores, and when mixed into concrete, they require a higher addition of water (or pre-watering) than an aggregate of natural rock requires. The water-to-cement ratio of the concrete thereby becomes higher and, consequently, the strength becomes correspondingly lower.
3. In most industrial wastes, no expansion takes place during the sintering process. A lower volumetric weight of the aggregate is then achieved only by the effect of the pores and cavities that are produced in the pellets when the combustible and volatile components, usually carbon powder and water, escape. Even the pores in these pellets are open, which involves an unsatisfactory water-to-cement ratio in the manufacture of concrete.
4. Many industrial wastes have such a high sintering temperature or they are sintered within such a narrow range of temperatures that the control of the sintering process becomes expensive

and difficult to manage, or even totally impossible.

For example, when fly ash from coal-burning power plants is used, it is necessary to select the fraction or fractions that have the most favourable chemical and physical properties from the ash collected fro the electrofilters of the plants. The rest of the ash is unusable for this purpose.

5. The chemical and mineralogical composition of the industrial varies to a great extent. In unfavourable cases the sintering may take place at entirely unacceptable temperatures.

If, for example, iron is present in the ferri form (as trivalent) and the atmosphere in the sintering furnace is oxydating, the sintering takes place only at a high temperature, which is economically unfavourable. The core of the pellets, which is in a reducing environment because of remaining carbon particles, is, on the contrary, sintered, expands and swells, and is rigidified into a mass resembling lava. Sintering is a reducing atmosphere cannot be justified economically in respect of such inexpensive materials.

Thus, the requirement of economically and construction-technically acceptable lightweight aggregate made of industrial waste involves the following:

- The green pellets must be given such a strength that they stand the mechanical strain that is involved in the most favourable sintering process.
- The sintering must take place in a rotary kiln in order to permit and to facilitate a free expansion of the pellets and to restrict the sintering-together.
- Expansion of the pellets during the sintering must be stimulated by means of additives suitable for this purpose.
- The additives and the methods for their introduction must be selected such that both the green pelletizing and the sintering processes can be supervised and controlled.
- A sintering of the surface layer must take place at an early stage of the sintering process so that an impermeable film is formed that prevents the escape of the gases that cause the expansion.
- The composition of the surface layer of the pellets must be such that, under the prevailing conditions, the sintering begins in this layer before the sintering of the material in the core starts. An elastic film must be produced around the core, which film, owing to its density and elasticity, permits a homogeneous expansion of the core without uncontrolled escape of gases. The pellets hereby obtain a substantially spherical form and, above all, a structure with closed pores. These pellets do not adsorb water in the same way as lightweight aggregate sintered on a belt does, which circumstance, together with the spherical form, has a favourable effect on the requirement of water of the concrete with a predetermined consistency.

According to the invention, green pellets with such a physical and chemical composition are achieved that the nodules can be carried, without disturbing breaking, into the furnace, which may be a rotary kiln in the present case, and burnt therein with expansion. This expansion can be controlled by means of the properties of the sludge that is used when the green pellets are formed, on one hand, and by means of the burning time and temperature in the furnace, on the other hand.

The lightweight aggregate granules that are obtained by means of the generally known processes do not meet the requirements imposed.

The object of the present invention is to eliminate the drawbacks involved in the previously known processes for manufacturing lightweight aggregate.

The process in accordance with the present invention is mainly characterized in that

- the binder is a water-saturated binder, and
- the binder is sprayed in the form of sludge or liquid onto the basic material in connection with the formation of the green pellets.

According to the invention, the unmoistened finely divided material (fly ash, flotation waste, etc.) may be fed onto an inclined granulating plate, where a sludge is sprayed onto the material, which sludge consists of clay and/or of high-molecular organic substances functioning as a "size" (e.g. sulphite waste liquor, various cellulose derivatives, and equivalent).

The purpose of this sludge is to give the green pellets the mechanical strength required for the subsequent mechanical treatment, on one hand, and to give the green pellets such a chemical and mineralogical composition that the sintering becomes easier and is started in the surface layer of the green pellets before the generation of gas inside the pellets starts, on the other hand.

It is also possible to use non-expanding raw-materials for this purpose by using, in the green pelletizing phase, expanding clay and/or organic additives of the type mentioned above.

By means of the quantity and type of the sludge used in the green pelletizing phase, it is possible to modify the properties of the raw-material in a direction favourable for the sintering process, which is of great importance, e.g. when fly ashes of different kinds are pelletized. By means of the organic material, an oxydation of the ion compounds in the surface layer is prevented, which oxydation would result in a retarded sintering of the surface layer in relation to the interior of the pellets, as well as in cracking and deformation of the pellets.

The sintering, which is preferably performed in a multi-compartment rotary kiln in order to more easily supervise and control the drying-sintering process and the expansion process, results in a dense

surface layer which prevents the gases formed inside the pellets from escaping. Hereby a lightweight aggregate with closed pores is obtained, which closed pores are, from the concrete technology point of view, to be preferred to open pores. By selecting an appropriate combustion temperature and time, it is possible to prepare an aggregate of desired size, weight and strength out of one and the same starting material.

It is important that the clay sludge that is used in the green pelletizing process is saturated with water, i.e. that the clay does not absorb water from the clay sludge after the beginning of the process. This may happen if dried clay is used without a sufficiently long period of water-saturation.

The heat economy can also be improved as compared with the known processes, owing to the fact that the said additives result in reactions that produce expansive gases even at lower temperatures.

In sintering experiments in a rotary kiln it has been ascertained that the best pellets are achieved if the process is divided into several heat-treatment phases, i.e.

a) heating, elimination of moisture,
b) surface sintering, expansion in one or several steps, and
c) cooling.

In view of the possibility of supervision and control, these phases should be performed in several separate kiln compartments whose speed of rotation can be varied independently from each other.

Below, in the form of examples, the properties of pellets obtained by means of the process in accordance with the invention are indicated as compared with corresponding properties of pellets prepared by means of prior art processes.

EXAMPLE 1
Strength of green pellets

Green pellets were prepared on one and the same granulating plate by means of a known process out of fly ash alone and by spraying only water, on one hand, and in accordance with the invention out of the same fly ash and by spraying a clay sludge consisting of water-saturated clay and water, the invariable proportion of clay being 6 per cent of weight of the green pellet, on the other hand. The moisture content in both cases was 25 per cent by weight.

The green pellets were allowed to fall repeatedly from the height of 1 metre onto a concrete floor, and the number of falls until the appearance of the first visible crack was noted down.

The following average values were obtained:

| | |
|---|---|
| Fly ash + water alone: | 20 falls |
| Fly ash + clay sludge: | 39 falls |

All the green pellets had spherical form and the same diameter.

EXAMPLE 2

By means of the described process it is possible to obtain lightweight aggregate pellets of different degrees of expansion. In Table 1 some results are given that were obtained by burning in a muffle furnace.

TABLE 1

Expansion of nodules with a burning of 10 min. in a muffle furnace

| Raw Material + % of Weight of Binder of Total Dry Matter | Increase in volume | |
|---|---|---|
| | 20% | 100% |
| A Fly ash + 6% clay | 1202 °C | 1214 °C |
| B Fly ash + 15% clay | 1180 °C | 1203 °C |
| C Fly ash + 57% clay | 1161 °C | 1174 °C |
| D Fly ash + 5% sulfite waste liquor | 1196 °C | 1210 °C |
| E Flotation waste + 18% clay | 1152 °C | 1164 °C |

EXAMPLE 3

A number of mould boxes of 4 cm x 4 cm x 16 cm = 256 $cm^3$ were filled with equal volumes of sintered pellets of the type available on the market, on one hand, and of pellets in accordance with the invention, on the other hand. Subjected to vibration, the moulds were filled with one and the same

cement paste having the water-to-cement ratio = 0.33. Removal of the mould took place after one day and test pressing after 3 days. The diameter of the pellets was 10 to 12 mm.

The following results were obtained:

TABLE 2

Properties of lightweight aggregates

| Material | Volumetric weight (g/l) | Water absorption 5 mm (%) | Water absorption 1 h (%) | Porosity | Pressure Resistance (MN/m²) |
|---|---|---|---|---|---|
| A | 1538 | 1.3 | 1.4 | 43.2 | 35.2 |
| B | 1350 | 1.5 | 1.9 | 49.6 | 31.5 |
| C | 1577 | 0.6 | 0.9 | 39.3 | 32.2 |
| D | 1633 | 1.8 | 3.8 | 45.4 | 35.0 |
| E | 2000 | 0.6 | 0.9 | 32.8 | 34.1 |
| F (clay-based) | 600 | 24 | 26 | | 12.8 |
| G (Fly-ash-based) | 1530 | 12 | 15 | 41.9 | 21.1 |

A to E: Lightweight aggregate types prepared in accordance with the invention.

F and G: Commercial lightweight aggregate types.

Pressure resistance was measured on 10 to 12 mm aggregate in cement mortar.

The pellets prepared in accordance with the invention were heavier, but the proportionally higher strength places them in a class that is profitable from the point of view of concrete economy.

CLAIMS

1. A process for manufacturing lightweight aggregate pellets out of finely divided industrial waste, such as fly ash, enrichment and flotation waste, and dust, as basic material according to which process:

(a) at least one water-saturated binder in fluid form is sprayed onto the basic material;

(b) green pellets are manufactured in a way known per se out of the basic material and the binder; and

(c) the green pellets are sintered in a rotary kiln to form the final lightweight aggregate pellets.

2. A process as claimed in Claim 1, wherein the spraying is carried out by means of nozzles.

3. A process as claimed in Claim 1, wherein the spraying is carried out intermittently.

4. A process as claimed in Claim 1, wherein the spraying is carried out continuously.

5. A process as claimed in Claim 1, wherein water-saturated clay is used as a binder.

6. A process as claimed in Claim 1, wherein organic materials having high molecular weight, such as sulphite waste liquor or similar, are used as binder.

7. A process as claimed in Claim 5, wherein the industrial waste is fly ash, and the proportion of clay is 5 to 15 per cent of weight of the total dry matter.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1981. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.